Comparison of L1B Product with Sensor Specification

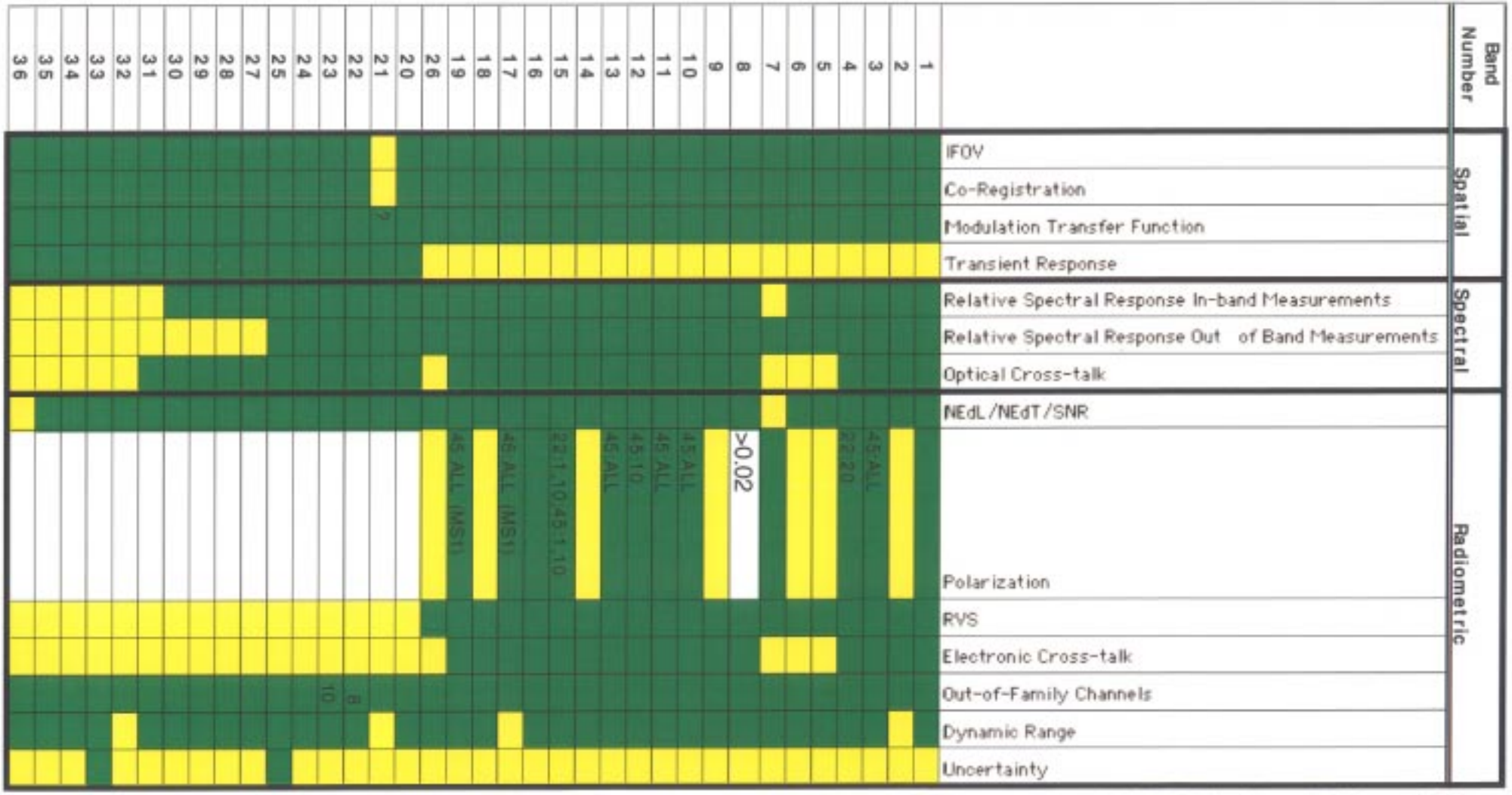
Outline

- **Key PFM Performance and Calibration Issues**
- **MCST Comparison of L1B Product with Sensor Specifications**
- **Reflectance Bands Transient Response**
- **˚Performance**
- **MCST Prototype Scene Restoration**

Key PFM Performance and Calibration Issues

- **Electrical Cross-talk mitigated. Residual effects to be evaluated on-orbit.**
- **L1B optical cross-talk reduction algorithms in place for Bands 5,6 (5.4 micron leak) and Bands 32-36 (Band 31 leak).**
- **Transient response specification not met for any Reflective Band**
- **Thermal Bands RVS adopted from FM1 and NPL witness sample measurements.**
- **Bands 5-7, 20-30 pre-launch calibration suspect; to be updated on-orbit; increased TEB uncertainty due to limited ability to measure non-linearity over OBC BB temperature range**

Comparison of L1B Product with Specification

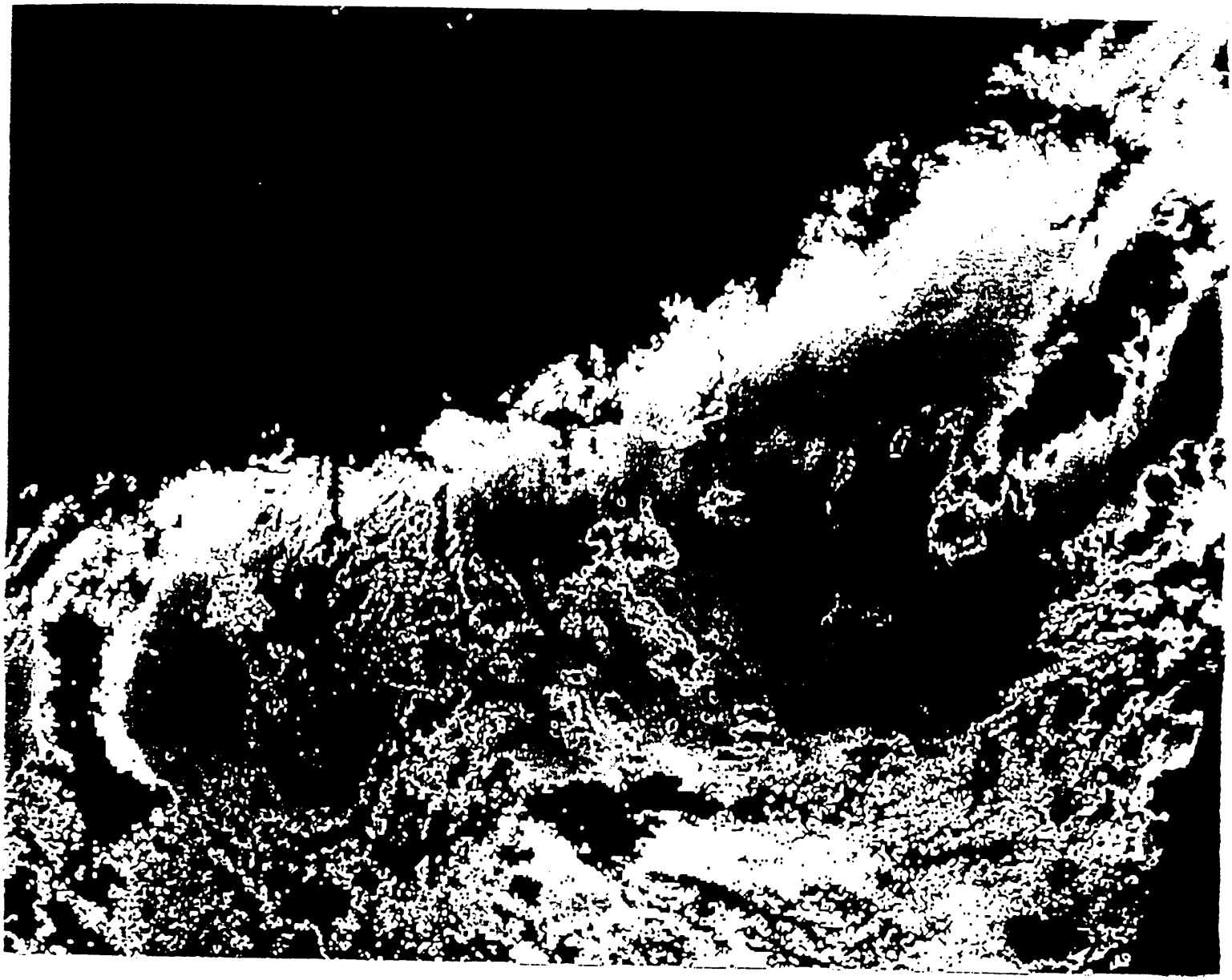


Reflectance Bands Transient Response ˚Performance

- Watson Gregg chart here

OCTS L_g 865 blacke low white = high

Blacke cloud saturation



865 nm = OCTS Band 8

W. Gregg

Prototype Scene Restoration

Section Divider

Key Issues Regarding Image Restoration

1) Which bands do we target for restoration? Ocean Bands 8-16?

2) What are scattering effects on various science product algorithms? Do ocean product algorithms require absolute radiometric accuracy, or is relative accuracy sufficient? How does scattering affect band ratio algorithms, band difference algorithms, etc.?

3) How do we handle MODIS cloud saturation? Can we use spectrally close unsaturated bands? Use similar MISR bands?

4) On-the-fly processing of 100% of data versus off-line processing of x% of the data. Desaturation of cloud tops may practically limit us to off-line processing.

5) How do we select x% of the data to provide useful results for science users? e.g., 10 scenes/day (3 granule scenes: 600 scans x 1354 frames)?

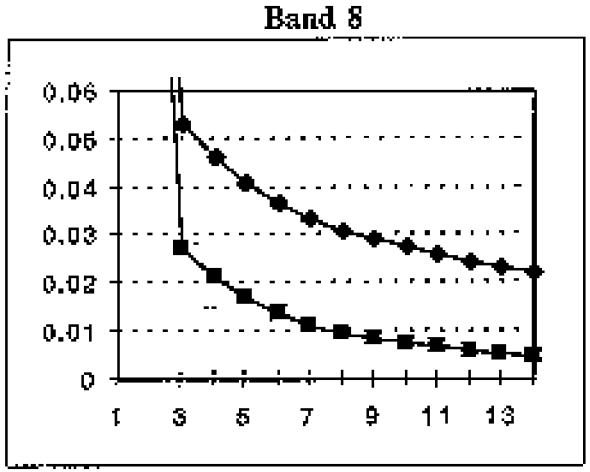
6) How accurately do we need to know the PSF to "do good and avoid harm" to the data? Can we model the PSF this accurately? Can we validate the far-field component of our PSFs using Moon scatter results?

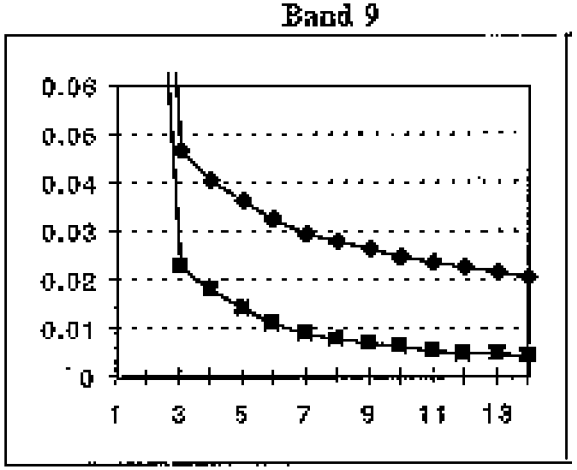
7) How large should the PSF be to get suitably accurate results?

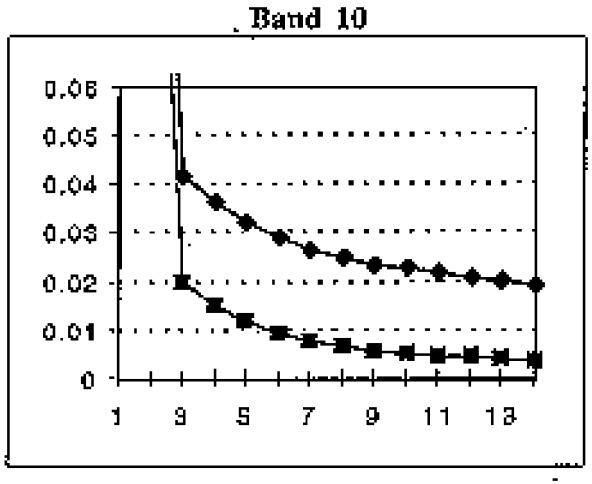
8) What are the restoration error effects due to imperfect desaturation of clouds?

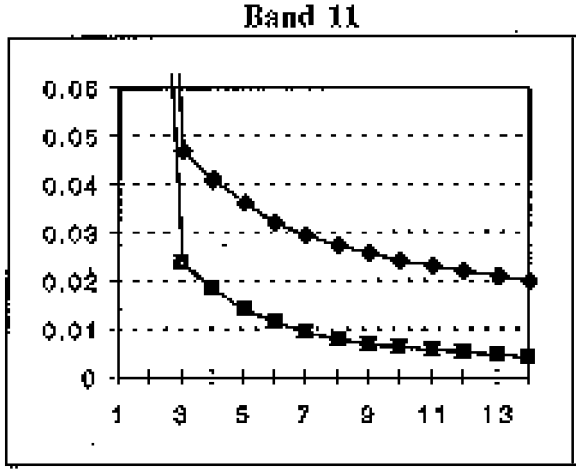
9) What are the restoration error effects due to filling data beyond measured scene to enable FFT processing?

Figures for 20x20 and 120x120 bands 8-11

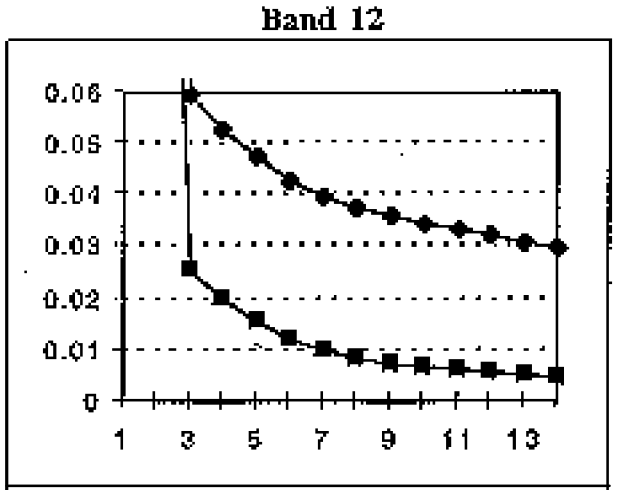


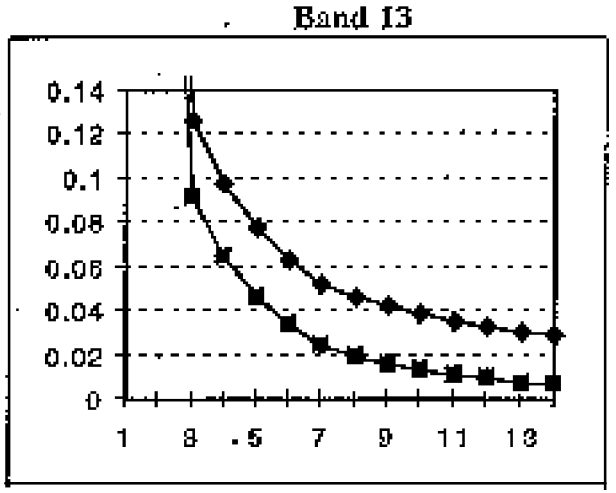


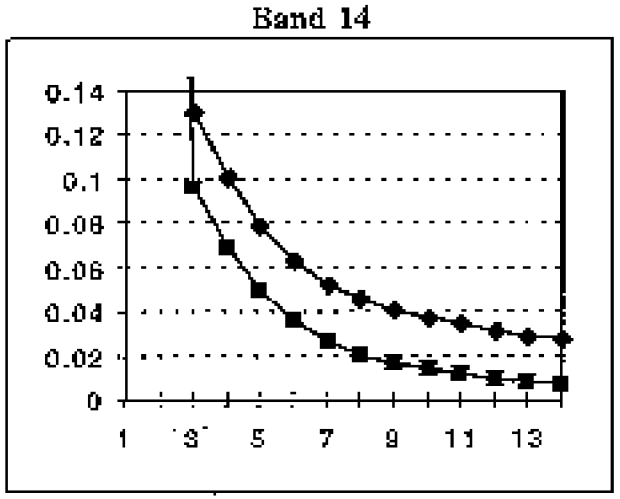


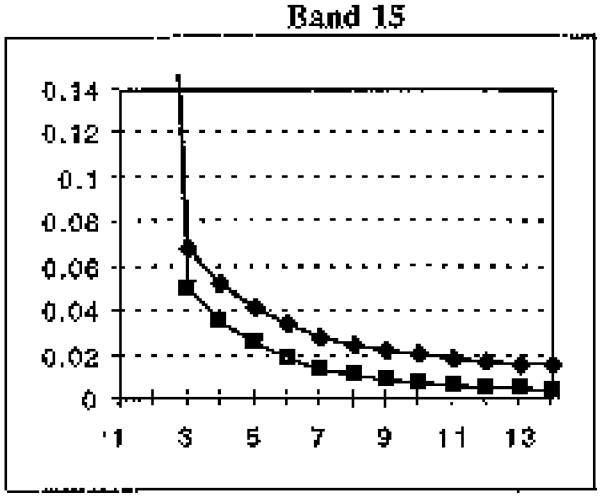


Figures for 20x20 and 120x120 bands 12-15

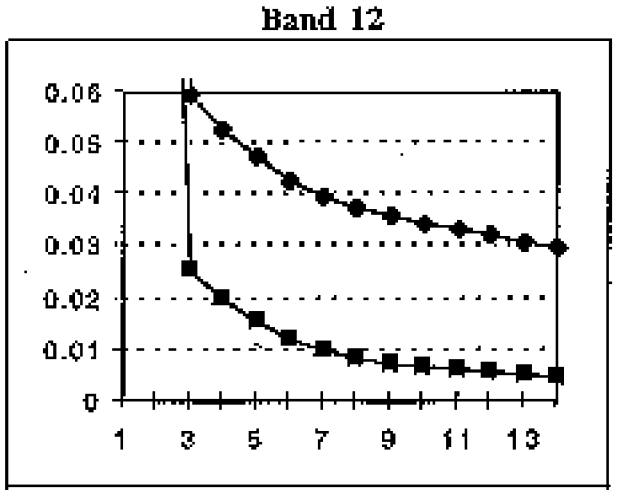


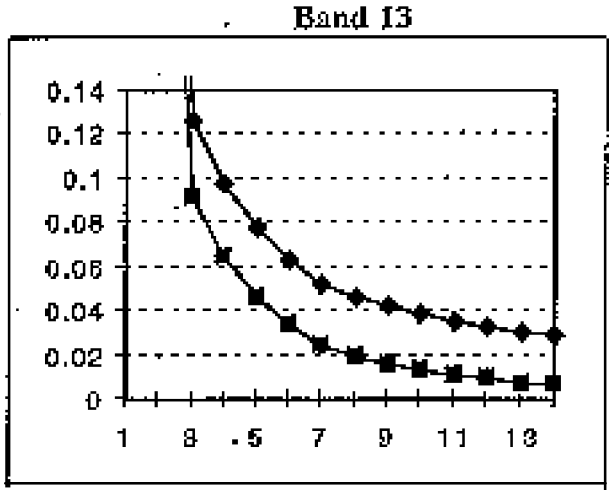


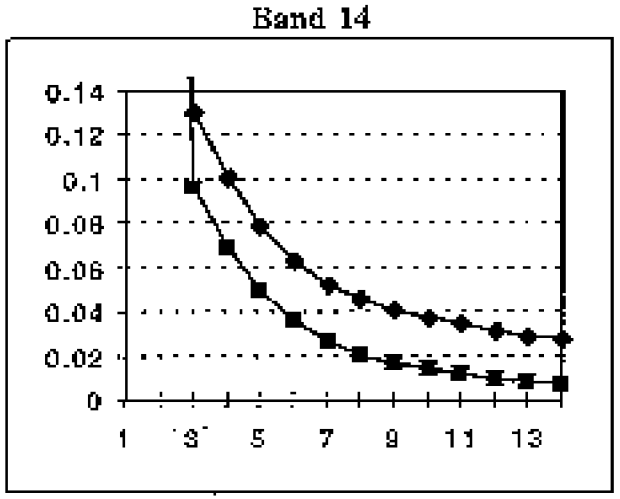


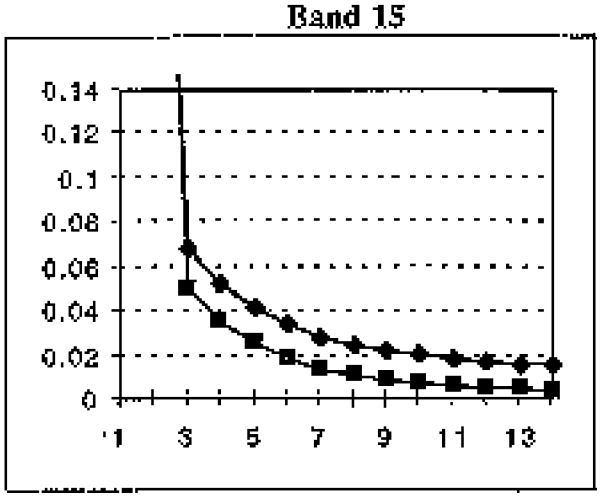


Figures for 20x20 and 120x120 bands 12-15







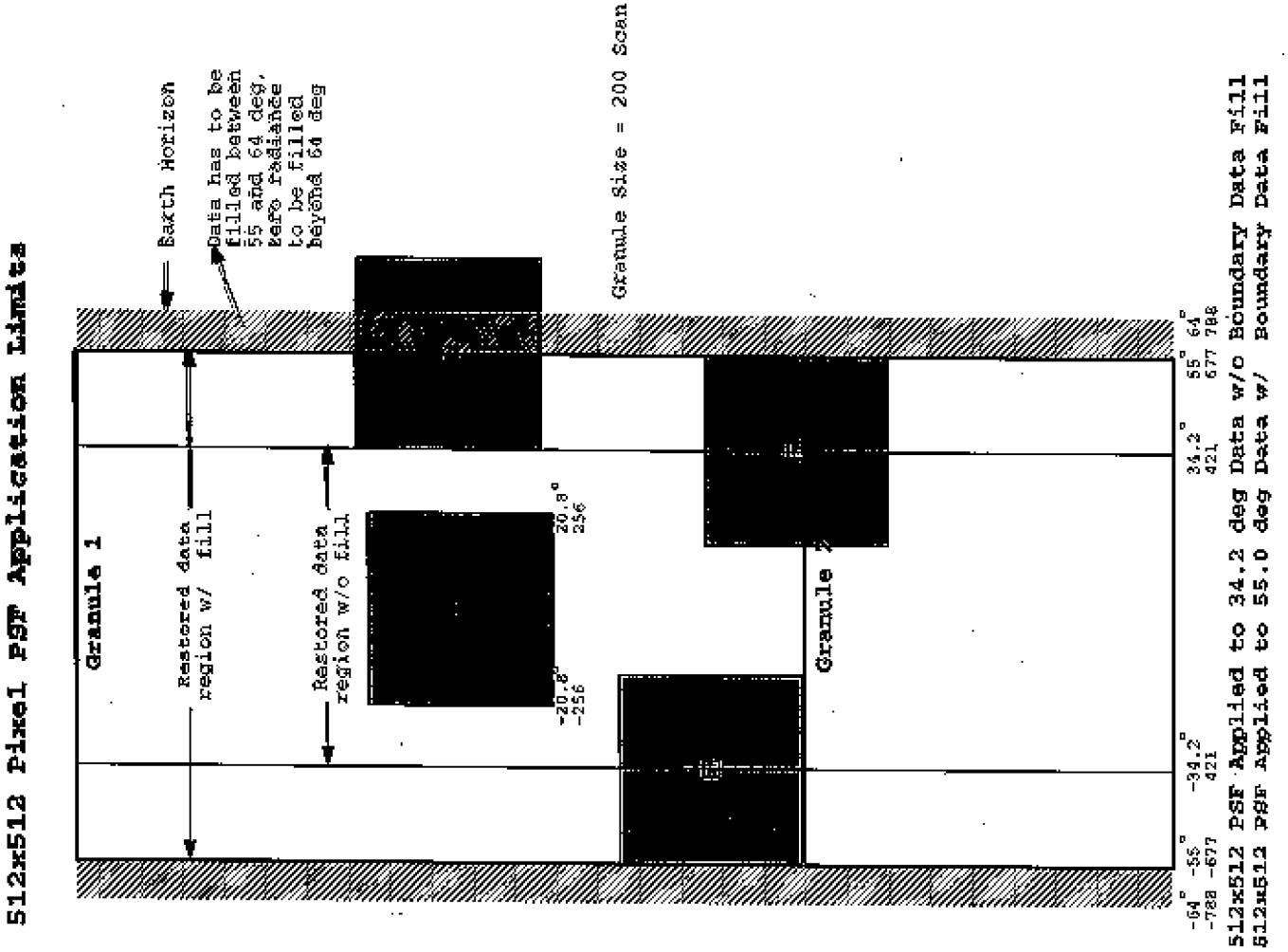


Reflectance Bands Transient Response Performance

WORD OF CAUTION TO L1B USERS!

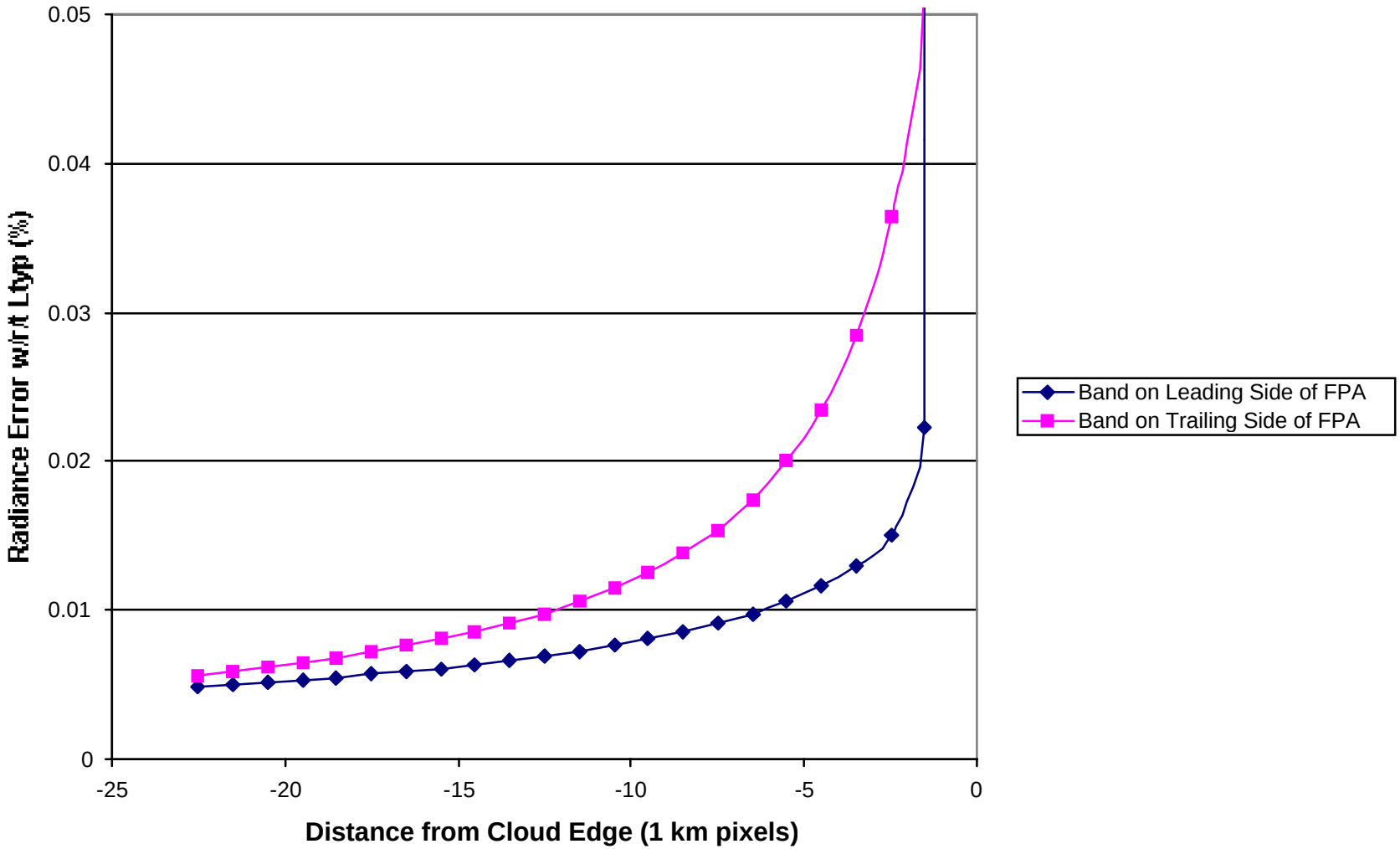
- **Expect significant radiance bias errors near high contrast features (0 to 30 km region depending on contrast ratios)**
  - Bright clouds over ocean or dark forest
  - Land/ocean shore lines
  - Estuary regions
  - Ice/snow boundaries near water
  - Other TBD aspects of data with high contrast ”nearby”
- **No schedule at present for incorporating Scene Contrast Index into the L1B product**

512x512 Pixel PSF Application Limits

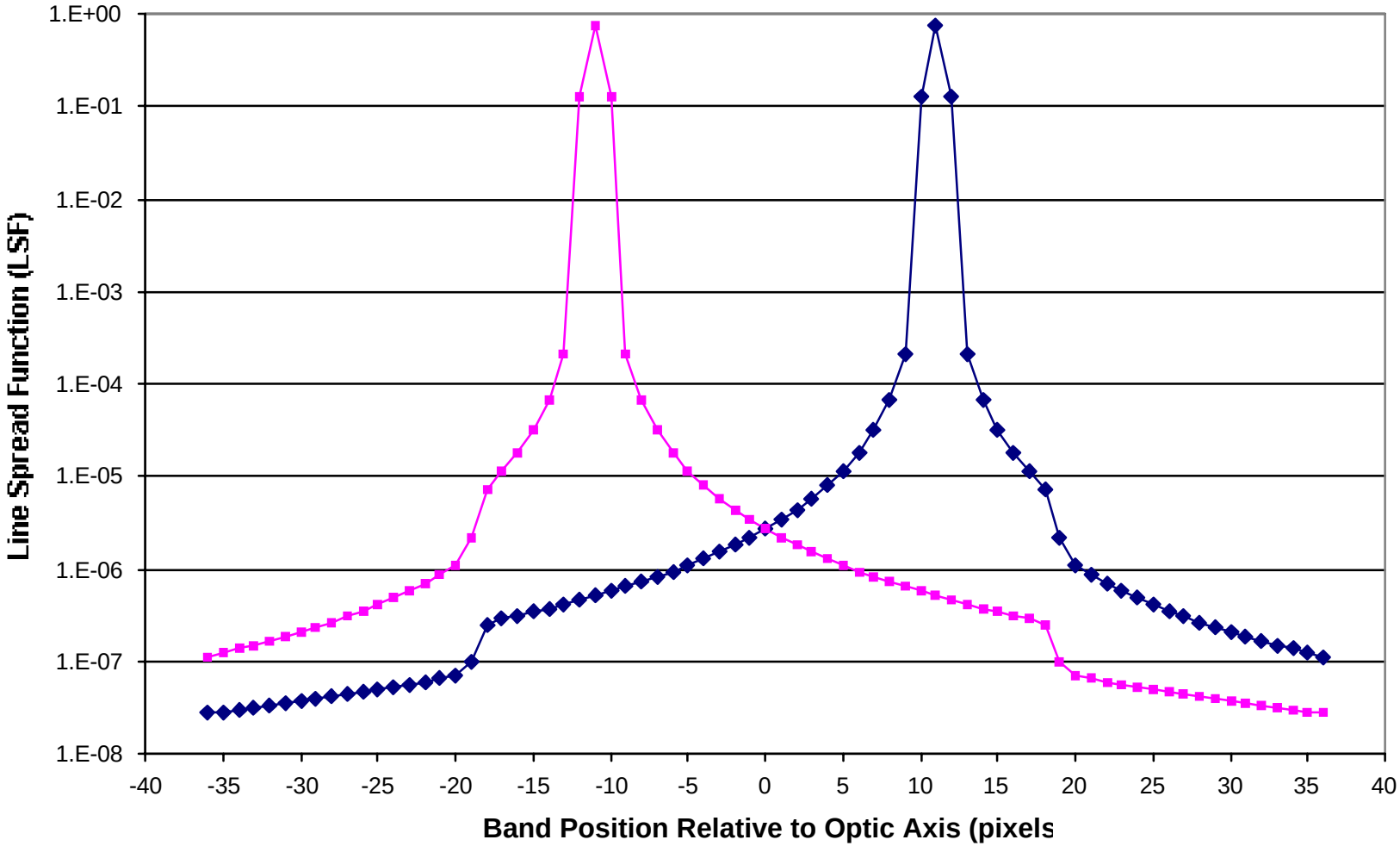


Radiance Error for Two Band Locations on FPA for Lcloud/Ltyp=20

(scanning from ocean onto cloud; both bands have same spectral characteristics)

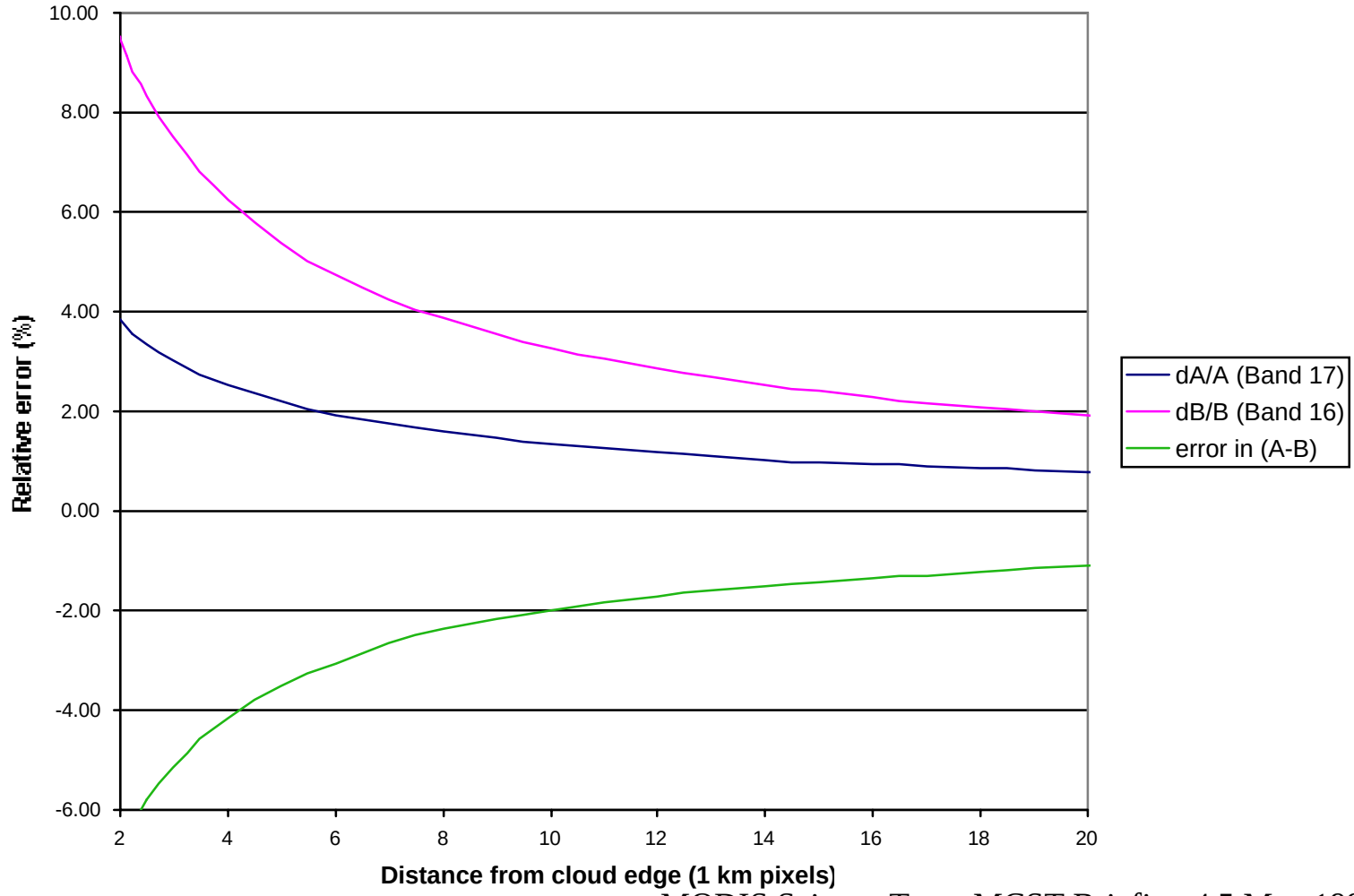


Line Spread Functions for two identical bands located on far-left and far-right of FPA



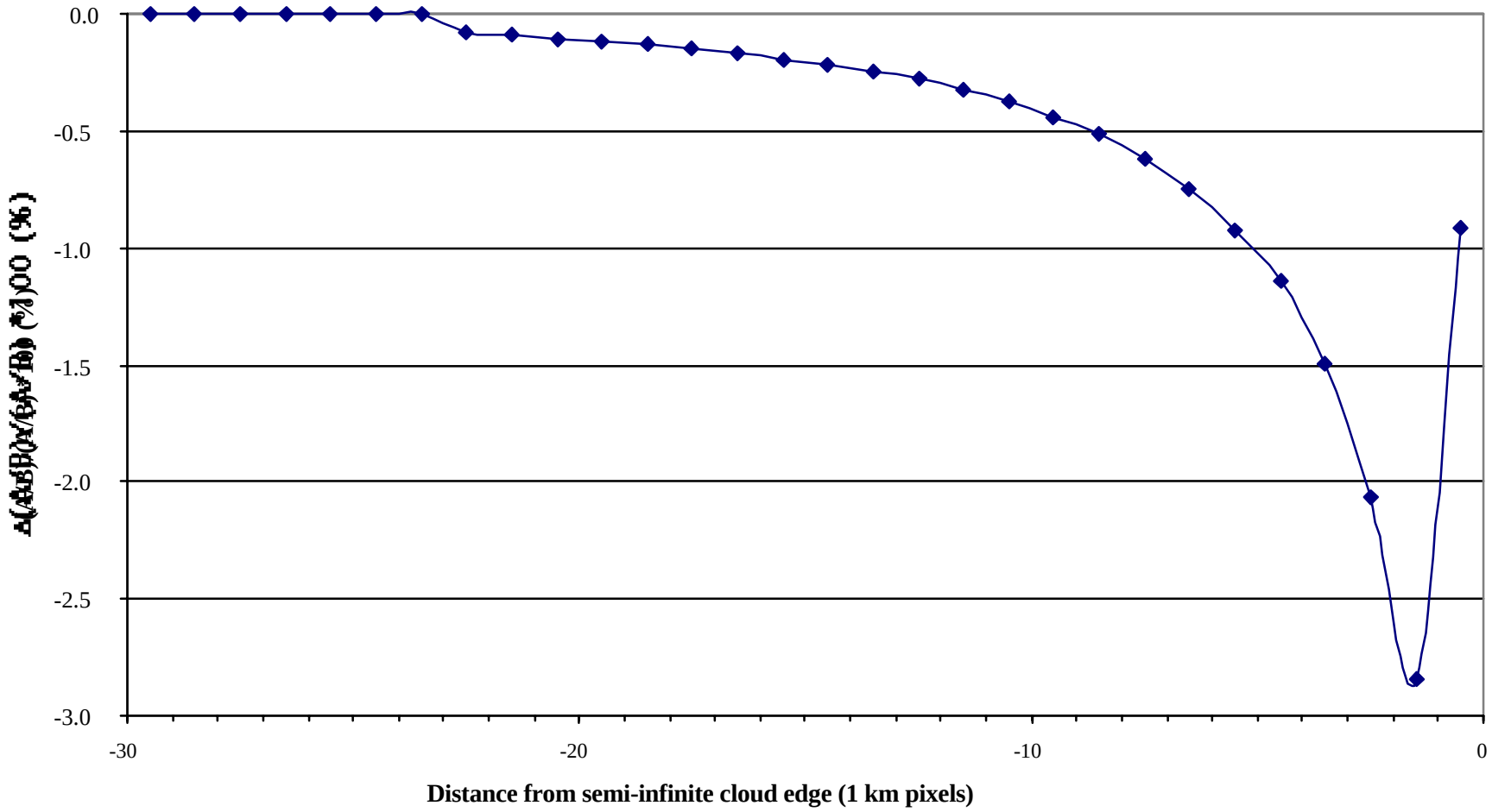
Absolute radiance errors compared to relative error for A-B type algorithm

(MODIS Band 16@887 nm with Lcloud/Ltyp-46; and Band 17@904 nm with Lcloud/Ltyp=25.2)



Effect of spectral band location within FPA on A/B type algorithms

(Band A on far left; Band B on far right;
scanning from Ltypical onto semi-infinite cloud, with Lcloud/Ltyp=20)



Instrument Activation Sequence

Section Divider

Instrument Activation Sequence

Outline

- Identify our guiding objectives
- Describe what we are going to do
- Provide major milestones

Identify guiding objectives

- **Safely turn-on MODIS**
- **SBRS Verify nominal functionality**
- **Establish accurate on-orbit performance**
  - Compare on-orbit performance via On-Board Calibrators over operational parameter space with pre-launch performance
- **Establish early performance baselines and trend variation from that performance**
- **Promptly compare pre-launch Reflectance Bands radiance calibrations (SIS100) with on-orbit solar diffuser and TOA solar irradiance (Thuellier) derived radiance values**
- **Initiate vicarious validation activities with surface sites and field campaigns as available**

Operating Constraints

- **Spacecraft final orbit achieved ~ at Day 12**
- **Contamination and Water Vapor outgassing**
  - 14-day cold focal plane assembly bakeout prior to cool-down
- **Door operations**
  - Prefer open NADIR and Cooler doors once only
- **Work from 48 hour command baseline**
- **Bands 1-19 not telemetered for night mode data**

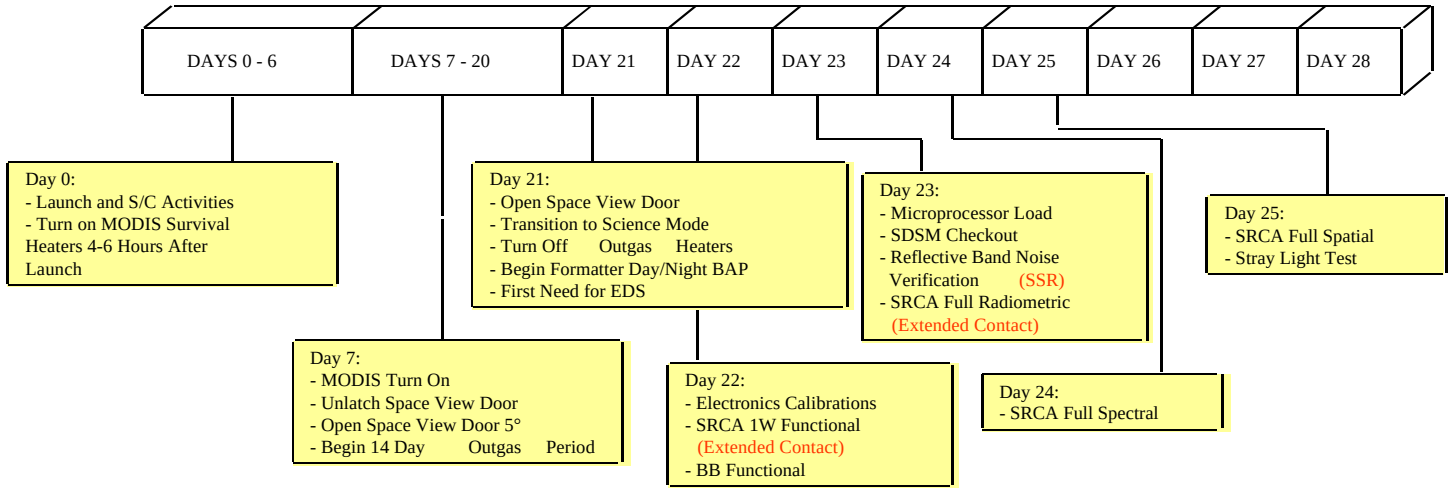
What we are going to do

- **Focal Plane Assemblies operating voltages**
- **SWIR bands thermal leaks**
- **Residual electronic cross-talk shadows assessment**
- **SD/SDSM baselines**
- **SRCA testing**
- **Band 31 leak into Bands 32 - 36**
- **Response vs. Scan Angle via scene statistics**
- **Transient response/scene sharpening**

ITEMS MARKED BY UNDERLINE MUST BE ACCOMPLISHED WITHIN 30 DAYS AFTER FIRST LIGHT

Launch and Early Orbit Operations - I

MODIS L&EO Phase Operations



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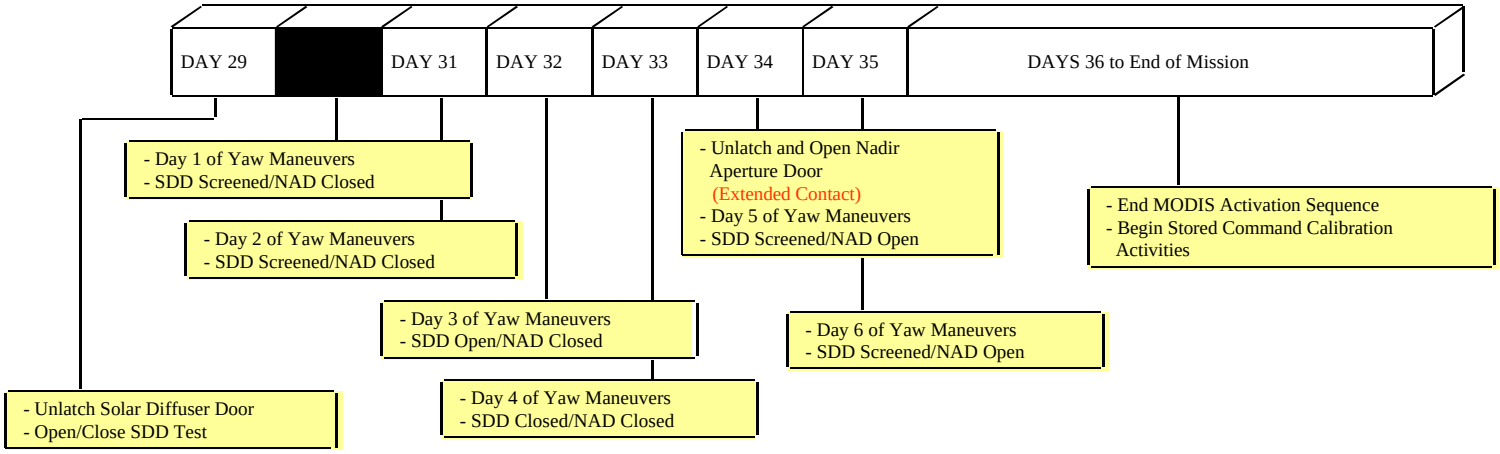
Launch and Early Orbit Operations - II

MODIS L&EO Phase Operations



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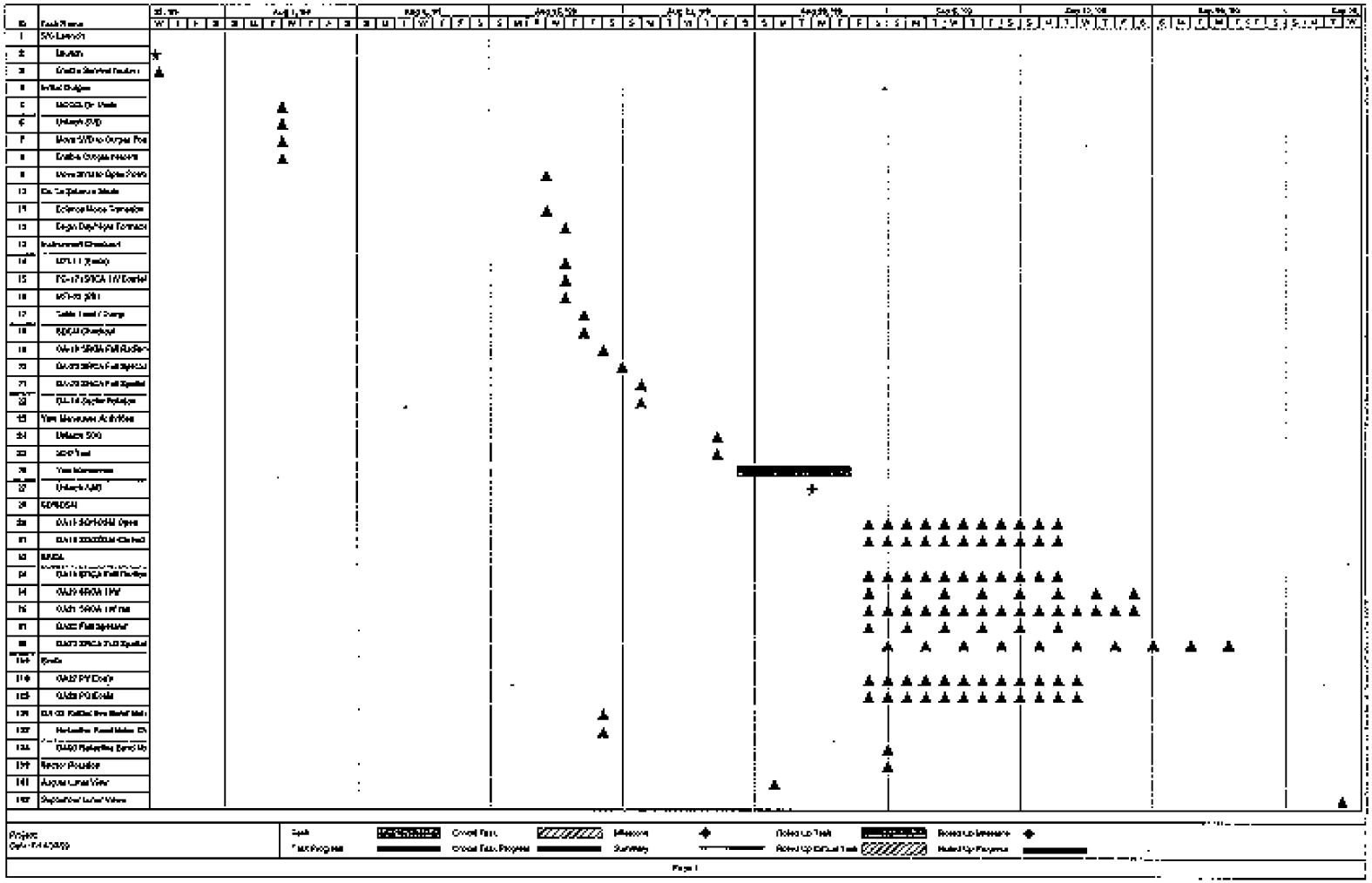
A&E Operations Gannt Chart



Major Milestone Planning Goals (Launch = Day 0)

PRECURSOR EVENTS: NADIR DOOR OPEN (DAY 34), L1A AVAILABLE IMMEDIATELY AND SBRS RELEASES SENSOR FOR SCIENCE

- First Light image w/pre-launch calibration **Day 36**
- Internal L1B product available with 1st calibration and code modification updates **Day 49**
- On-orbit spectral calibration and co-registration via SRCA observations **Day 49**
- L1B files for science checking of L2 code **Day 64**
- First Calibration Validation Workshop **Day 124**

CAVEAT: ASSUMES SUCCESS-ORIENTED INSTRUMENT CHECKOUT AND EDOS/DAAC/CROM DATA OPERATIONS

Impact on SWIR Calibrations of Science Operations Begin Day 30

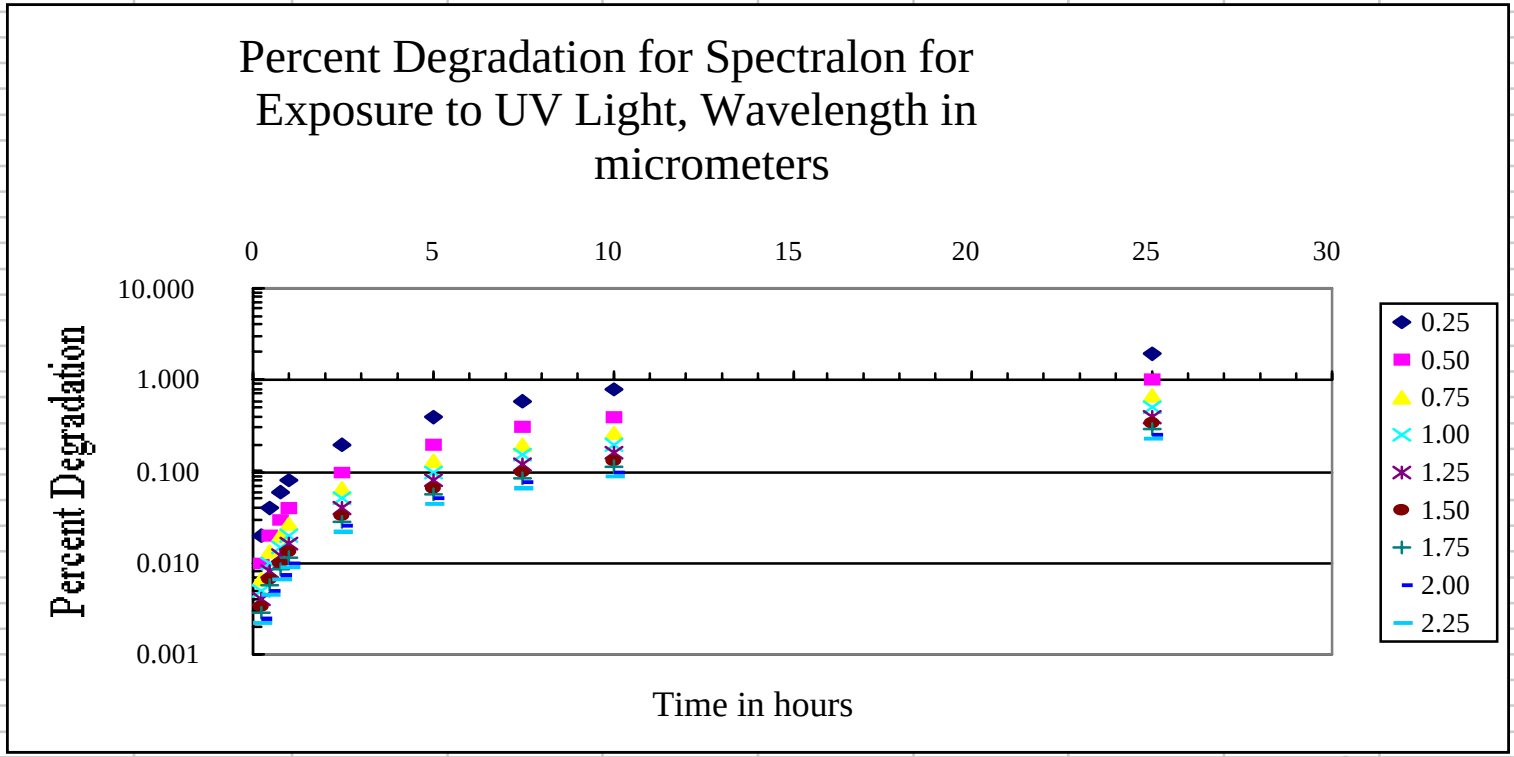
- No SWIR Bands in SDSM, so lunar calibrations needed to track SWIR SD degradation
- What is risk if initial SD observations not matched to 1st lunar observation
  - May delay initiation of science operations by up to 28 days
  - Models of SD degradation in SWIR indicate about 0.1% degradation or less likely in first 30 days of SD operations
  - Will pick-up SD trending with 1st lunar observations regardless of extent of degradation
- Conclusion: little risk to start as planned

SD Degradation Model

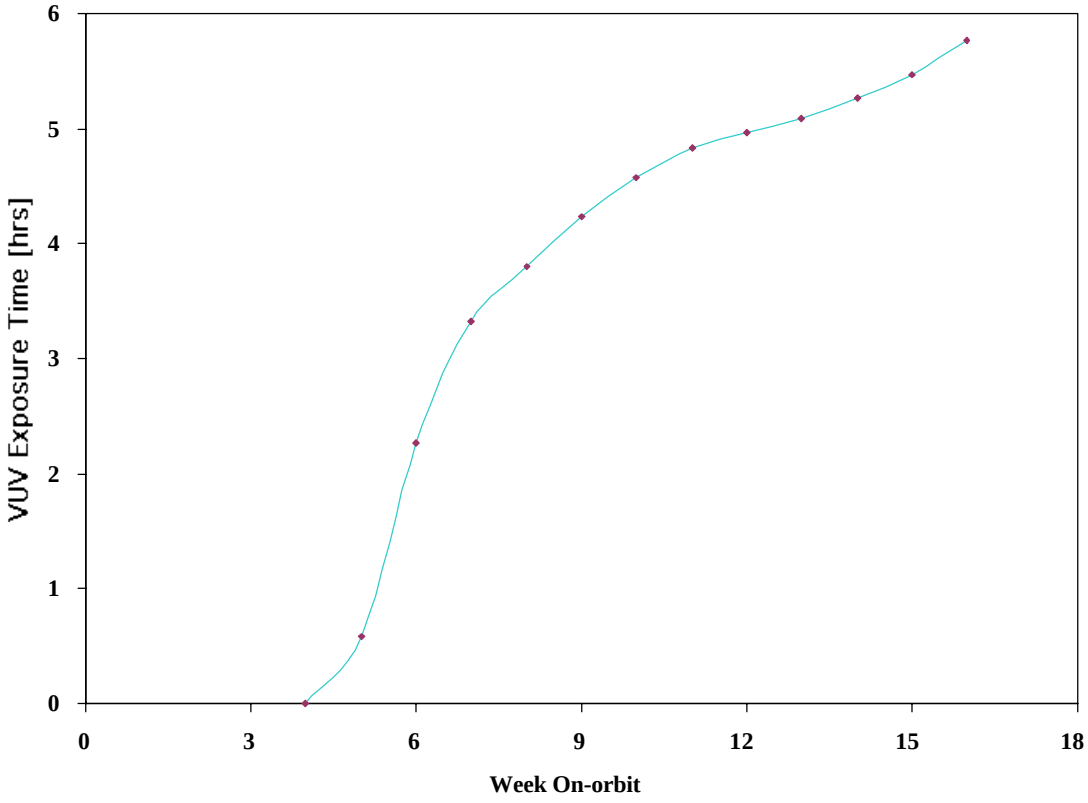
as exp(-c*time/wavelength)

c matched to lab data 0.05% at 1 hour @ 400 nm

Wavelength	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
0.25	2.000E-02	1.000E-02	6.666E-03	5.000E-03	4.000E-03	3.333E-03	2.857E-03	2.500E-03	2.222E-03
0.5	3.999E-02	2.000E-02	1.333E-02	1.000E-02	8.000E-03	6.666E-03	5.714E-03	5.000E-03	4.444E-03
0.75	5.998E-02	3.000E-02	2.000E-02	1.500E-02	1.200E-02	1.000E-02	8.571E-03	7.500E-03	6.666E-03
1	7.997E-02	3.999E-02	2.666E-02	2.000E-02	1.600E-02	1.333E-02	1.143E-02	1.000E-02	8.888E-03
2.5	1.998E-01	9.995E-02	6.664E-02	4.999E-02	3.999E-02	3.333E-02	2.857E-02	2.500E-02	2.222E-02
5	3.992E-01	1.998E-01	1.332E-01	9.995E-02	7.997E-02	6.664E-02	5.713E-02	4.999E-02	4.443E-02
7.5	5.982E-01	2.996E-01	1.998E-01	1.499E-01	1.199E-01	9.995E-02	8.568E-02	7.497E-02	6.664E-02
10	7.968E-01	3.992E-01	2.663E-01	1.998E-01	1.599E-01	1.332E-01	1.142E-01	9.995E-02	8.885E-02
25	1.980E+00	9.950E-01	6.644E-01	4.988E-01	3.992E-01	3.328E-01	2.853E-01	2.497E-01	2.220E-01



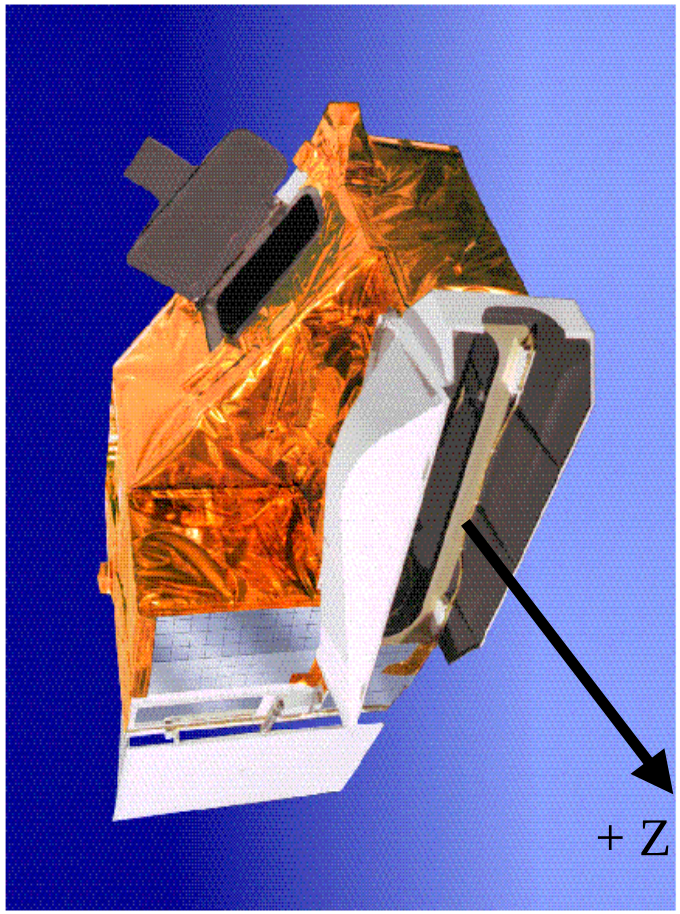
MODIS On-orbit VUV Exposure during A&E Phase



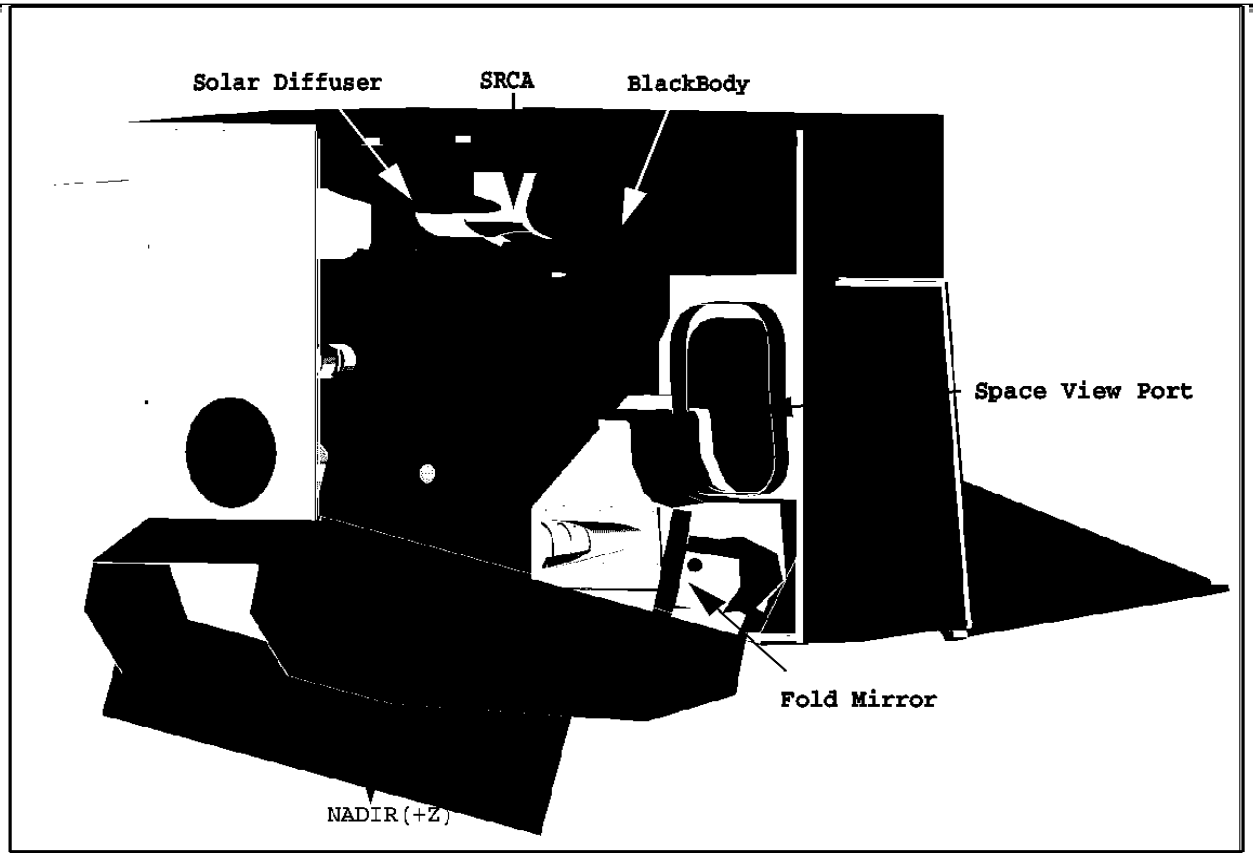
Week On-Orbit	Exposure Time [hrs]
4	0.00
5	0.59
6	2.26
7	3.33
8	3.80
9	4.23
10	4.58
11	4.83
12	4.96
13	5.09
14	5.26
15	5.48
16	5.77

Reference Charts

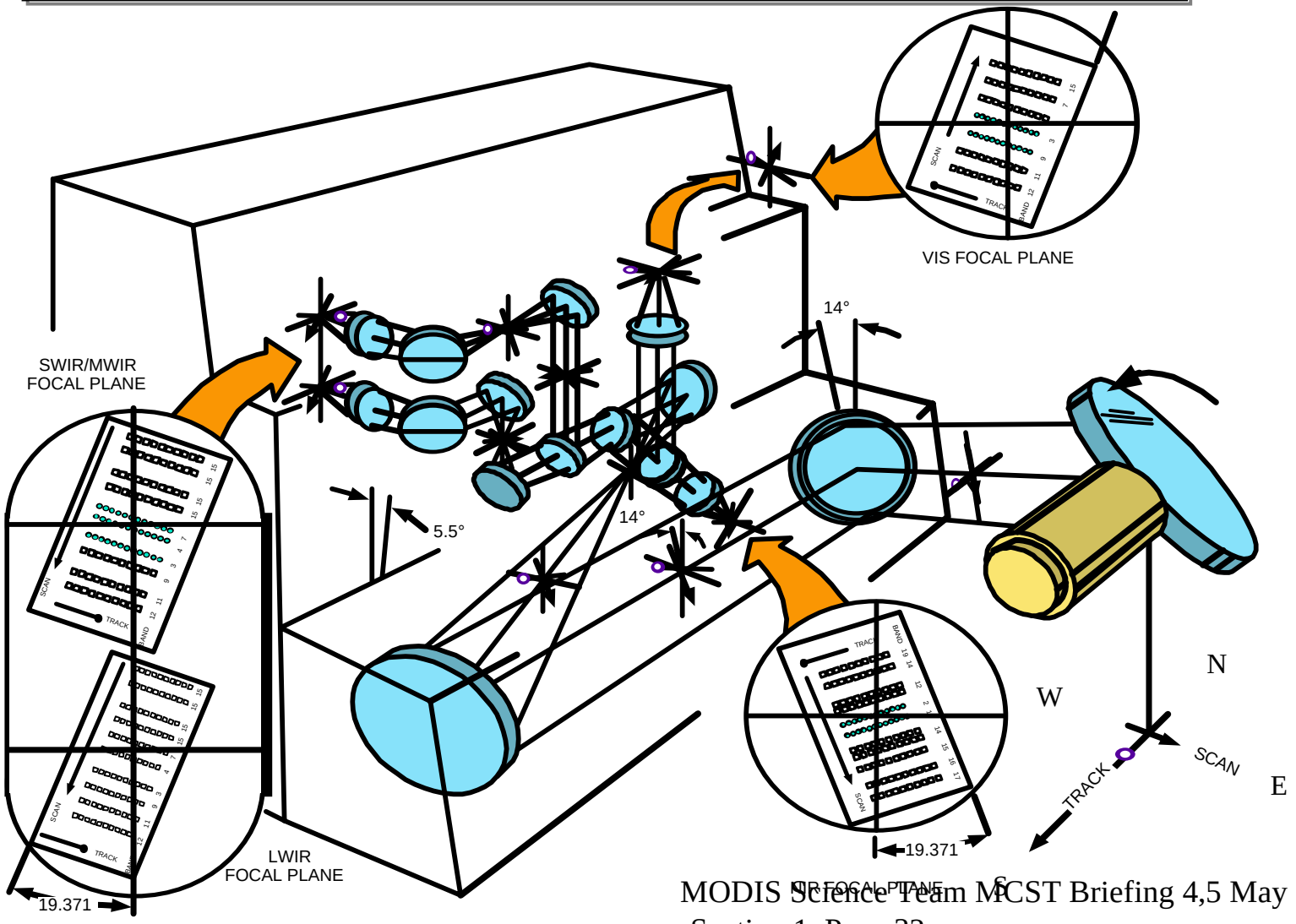
The MODIS ProtoFlight Model (PFM)

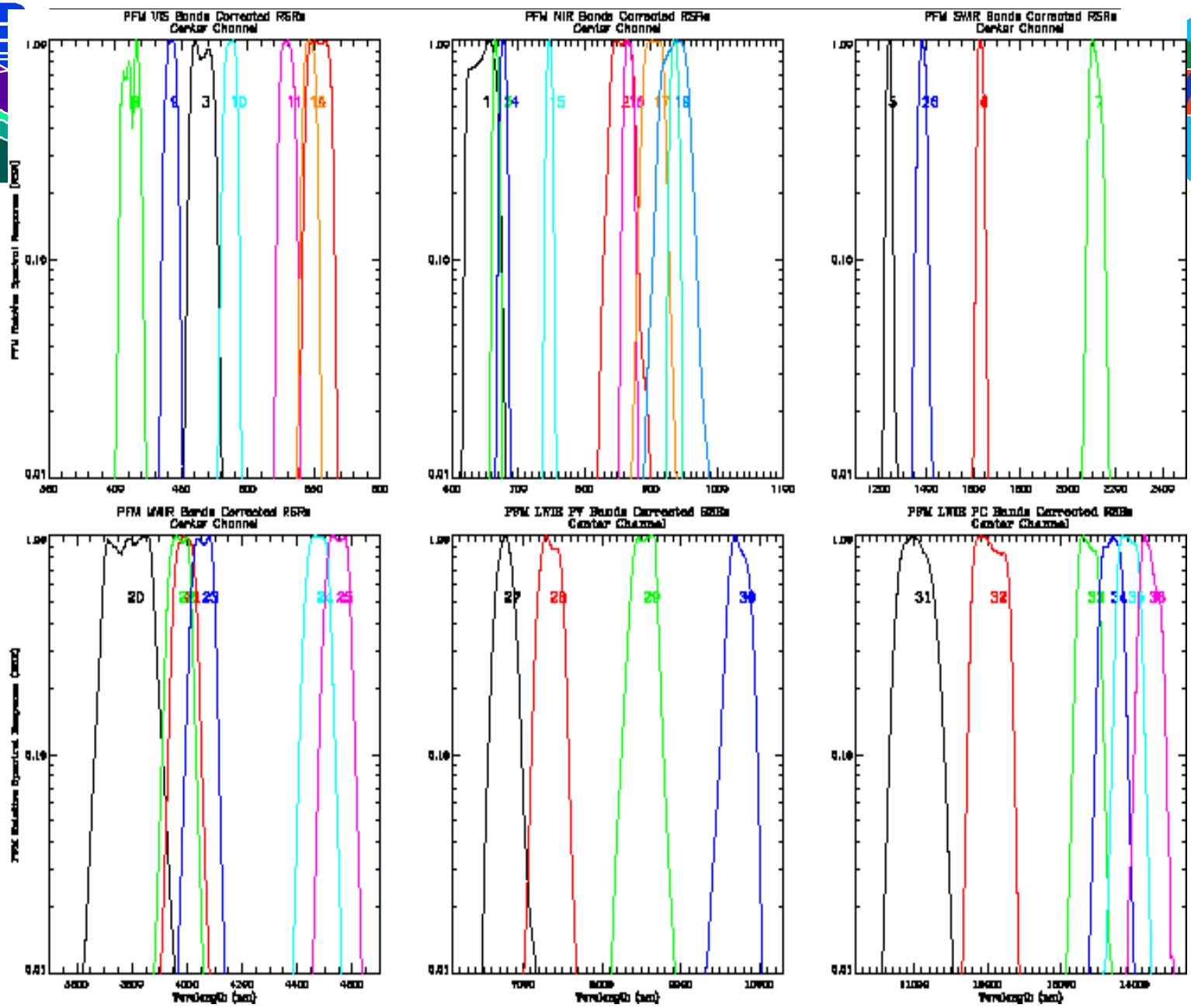


- Sensor on Terra S/C
- S/C at launch site
- 1.0 m x 1.0 m x 1.6 m
- 228 kg

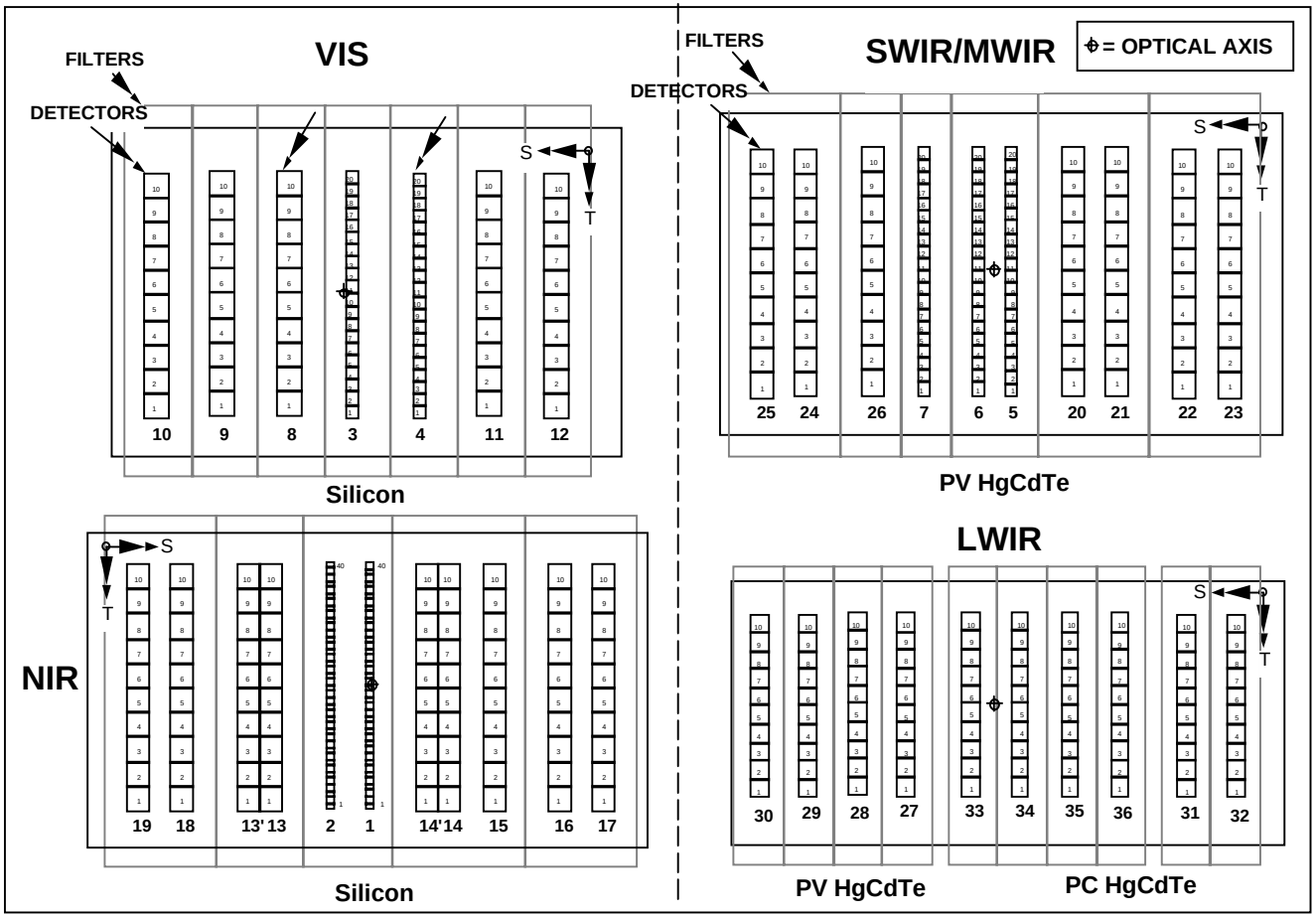

Solar Diffuser
SRCA
BlackBody
Space View Port
Fold Mirror
NADIR (+Z)

MODIS Optical System




PFM VIS Bands Corrected RSRs
Center Channel
PFM NIR Bands Corrected RSRs
Center Channel
PFM SWIR Bands Corrected RSRs
Center Channel
PFM MWIR Bands Corrected RSRs
Center Channel
PFM LWIR PV Bands Corrected RSRs
Center Channel
PFM LWIR PC Bands Corrected RSRs
Center Channel

MODIS Focal Plane Layouts



Instrument FPA Main Frame Temperature

Cold FPAs: (80. 83, 85k)

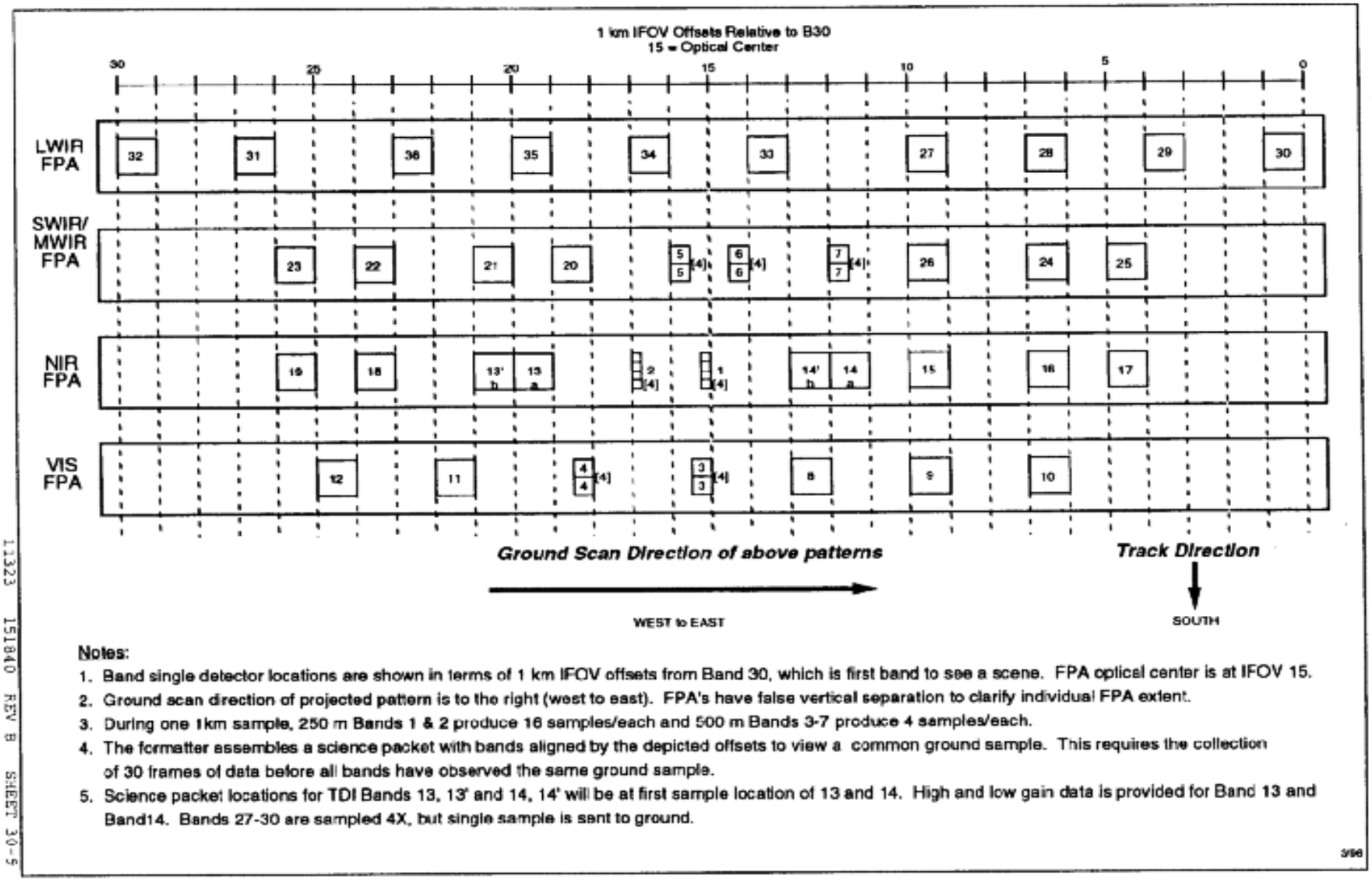


Figure 30-3. FPA Band Offsets Relative to Band 30

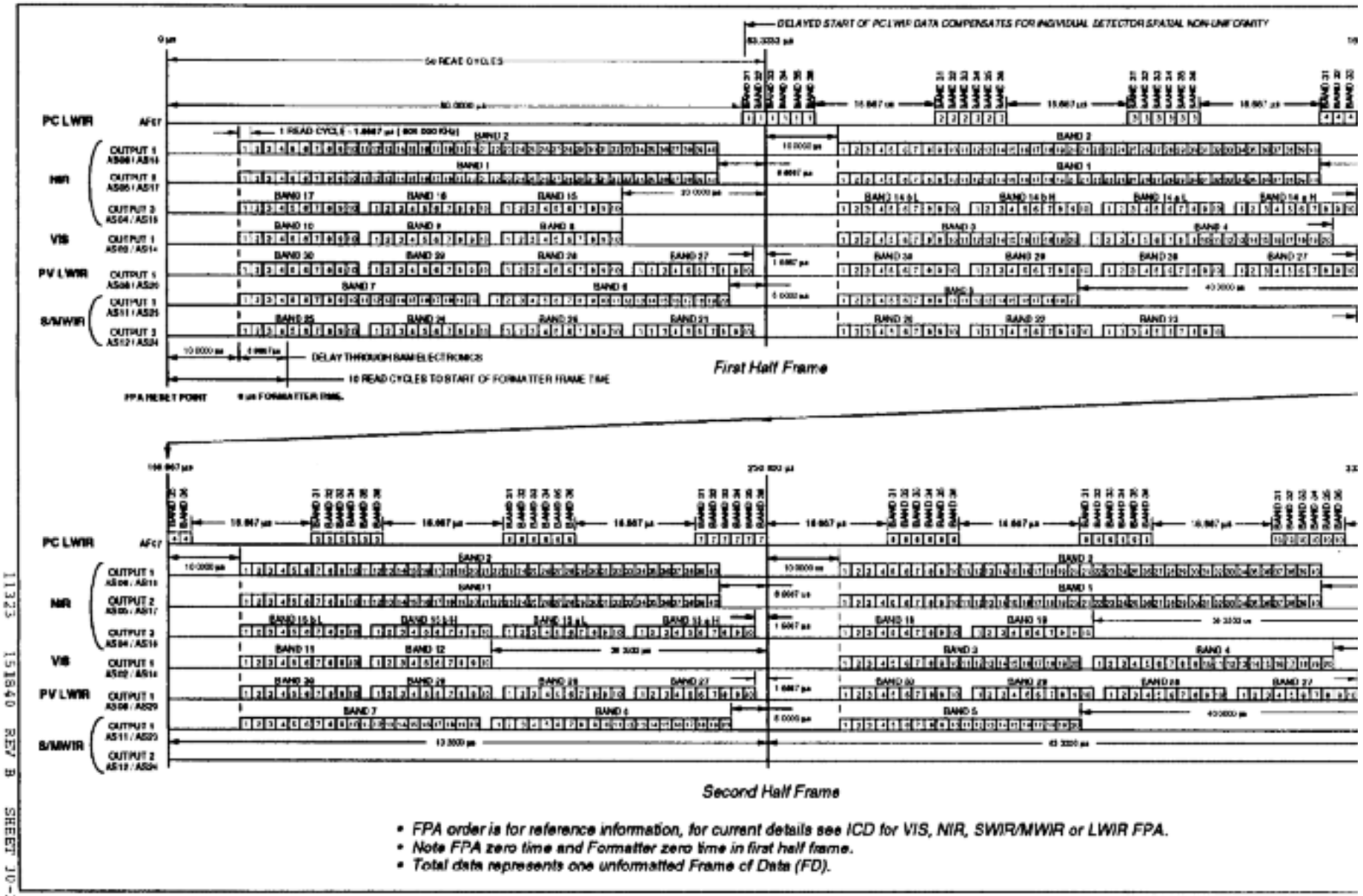
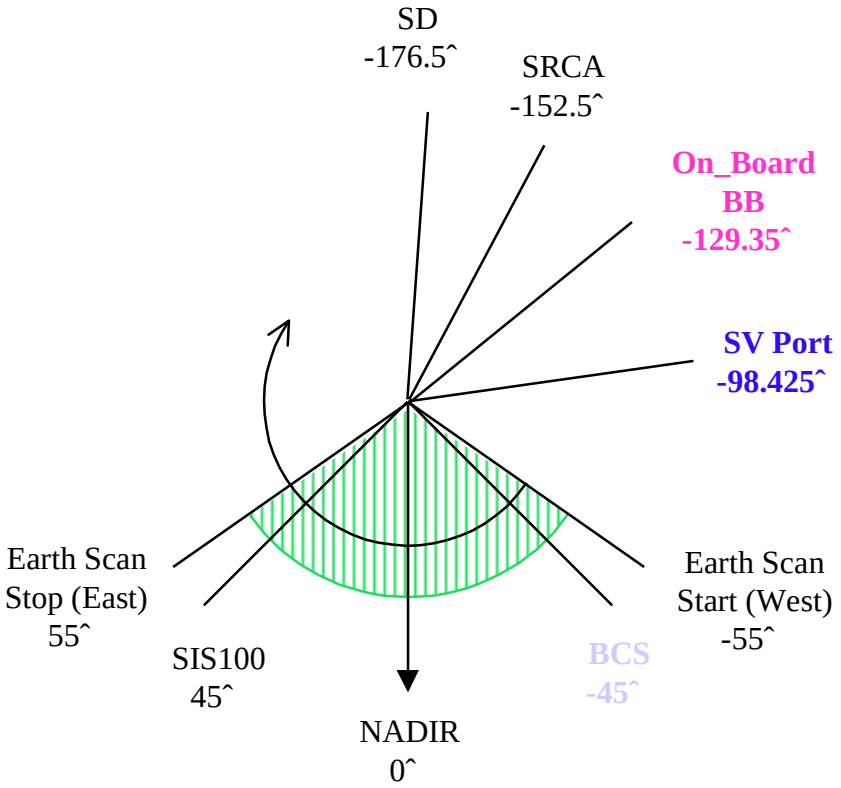
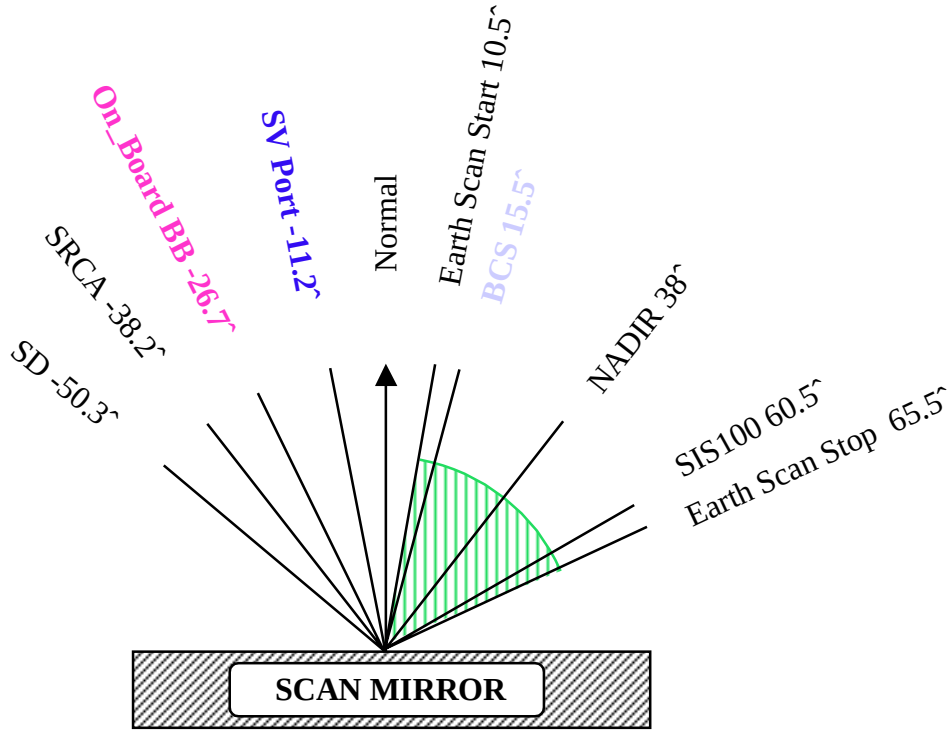


Figure 30-4. FPA Readout Order and Timing

Principal Scan Angles Mapped to Scan Mirror Angles of Incidence



Principal Scan Angles
(Earth View: -55ˆ to 55ˆ)



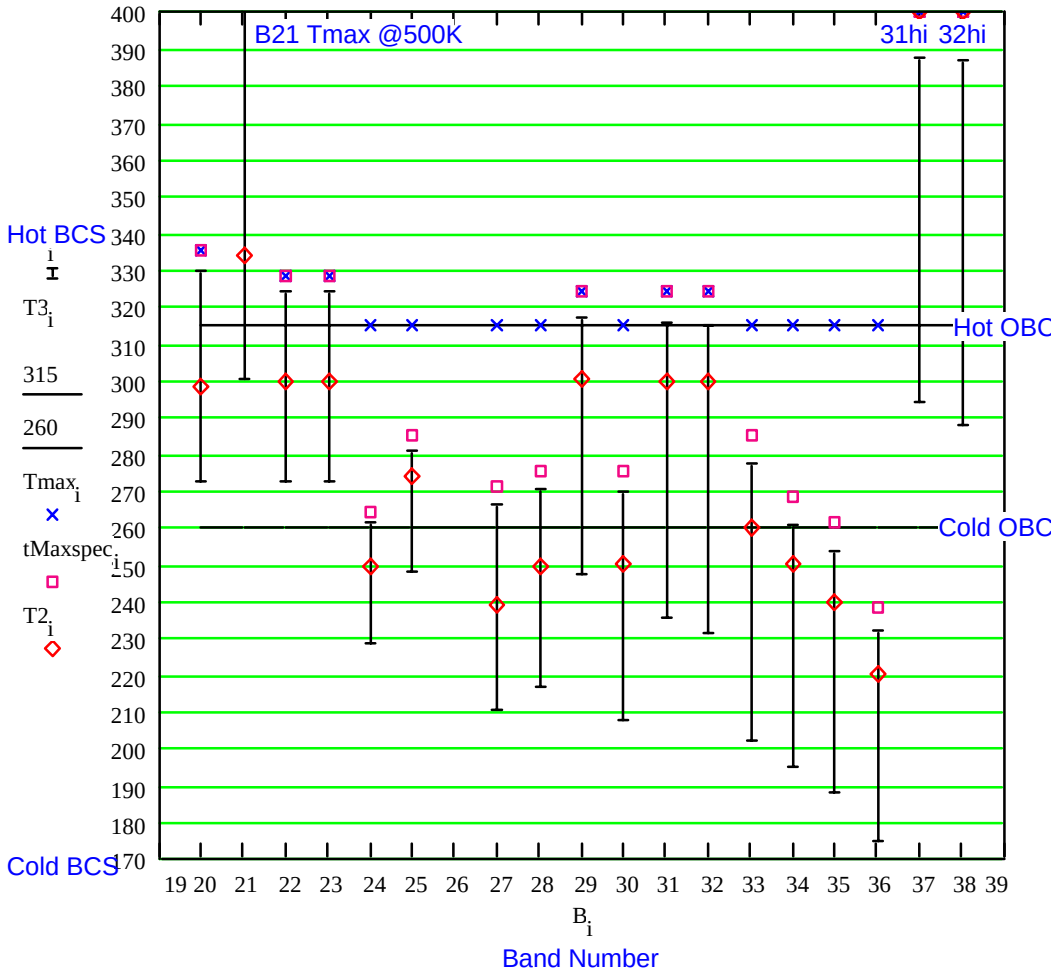
Angles of Incidence
(Earth View: 10.5ˆ to 65.5ˆ)

MST Requested Calibration Temperature Ranges for PFM

			Collect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
			CPT/ LPT	170	190	210	220	230	240	250	260	270	280	290	295	300	305	310	315	320	325	330	335	340
Band	Tcal_lo	Tcal_hi																						
20	220	330																						
21	260	340																						
22	220	325																						
23	220	325																						
24	220	315																						
25	240	315																						
27	210	315																						
28	210	315																						
29	210	318																						
30	210	315																						
31	220	316																						
32	220	315																						
33	190	315																						
34	190	315																						
35	170	315																						
36	170	315																						

BCS Temperatures Levels Used for Limited Performance Tests (LPTs) are noted with box outline.

MODIS Operational and Calibration Ranges



Vertical bars represent temperatures of 0.3Ltyp and 0.9 Lmax. Box symbols represent Tmax_spec, X symbols represent the value of Tmax_set (the higher of tMaxspec or 315K), a the diamond symbols represent the temperature of Ltyp

Back-up Charts

Notes for: Comparison of L1B Product with Sensor Specifications

Notes and References for the Comparison of L1B Product with Sensor Specifications are provided in accompanying Microsoft Word Document

Notes
Users of the L1B product are strongly encouraged to use the actual Relative Spectral Response values (RSR). Revision B of these is located at : **anonymous ftp site mcstftp.gsfc.nasa.gov, in /incoming/MCST/PFM_L1B_LUT_8-3-98 directory**.
Further direction may be found in the Readme file in that directory.
Items which are yellow identify either instances where

1. the test data is too noisy to interpret the characterization data set,
2. testing for this characteristic was not performed and MCST is not satisfied that the flight data sets will be transparent to this effect, or
3. test data indicates that the PFM L1B data product will not meet specification in terms of this characteristic.

In instances where a specification is not applicable to a band, the color used in the Chart is white.
In some instances the data set for a band is expected to generally meet the requirements, but there are some channels which are not within that specification. These cases are identified with channels numbers within the green cell that indicate which channels are not within specification. In the case of polarization, the requirement is polarization at a particular scan angle. The format here is scan angle first and channel number second.

IFOV
SBRS has submitted a waiver for channel-to-channel uniformity, VJ50-W079. Band 5, channel 17 (soft); Band 7, all bands marginal (virtually all laboratory data for the SWIR bands was noisy or saturated on PFM, so it is difficult to distinguish between sensor characterization performance failing to meet specification and merely inadequate test data to know the characteristic); Band 21 (test related) and Band 23 (marginal).

Co-Registration
SBRS has submitted Waiver WV081 for this characterization. The instrument failed to meet specification requirements for Spectral and Registration for one or more channels in Bands 3, 4, 5, 7, 12, 21, 27, 28, 29, 30, and 32. Some of this error likely was electronic cross-talk related, as each non-compliance involved at least one band which was impacted by electronic cross-talk. The MCST estimate is that these non-compliances will be transparent in the flight data set. Band 21 is marked yellow because it was not tested, due to low band gain characteristics.

Modulation Transfer Function
SBRS has submitted Waiver WV087 for this characterization. The bands identified in the Waiver all were impacted by electronic cross-talk. The cross-talk was minimized with a Space-viewing Analog Module resistor check, but no additional data has been obtained. This characteristic will be impacted by transient response characteristics.

Transient Response
SBRS has submitted a Waiver WV054 where they indicate that the sensor fails for all bands except Band 30. For Bands 20 to 30, these test data sets may have been impacted by electronic cross-talk.

Spectral

Relative Spectral Response In-band Measurements
The SBRS spectral response characteristics do not fully conform to specifications. This is documented in Waiver WV075. These non-compliances mainly are in center wavelength, band width and filter edge-range. Mainly these are minor. Actual use of the RSR will invalidate concerns with these non-compliances we expect.
The instrument used in testing in-band RSR has a slit function which did not fill the MODIS focal planes. Most bands were not well measured for the end channels, because the Spectral Measurement Assembly had a "smile" shape to the output slit function. The end channels for most bands were synthesized from the central channels for each band. This effect was well understood and the in-band RSR are considered well known. The uncertainty of the sensor specification for center wavelength does not correspond to that desired for the longest wavelength cloud bands (Band 33-36), so these are marked yellow. Also a light leak from Band 31 into Bands 32-36 contaminates the RSRs for these bands. Band 7 is yellow because the measurement saturated for this band.

Relative Spectral Response Out-of-band Measurements
SBRS submitted Waiver 063A to identify out-of spectral band compliance concerns.
The out-of-band measurements for Bands 27-36 are either not useful or were not performed on PFM. These values have been borrowed from the FM1 measurements and applied to PFM. This is expected to be a highly reliable assumption.

Optical Cross-talk
The blocking filters for the SWIR were not designed to extend across the complete sensitivity range of the SWIR detectors. The SWIR detectors for PFM had a longer wavelength cut-off than anticipated. Consequently, the SWIR bands have some sensitivity to thermal signals out to about 5.4 micrometers. This sensitivity ;is least for Band 7. The Bands 32 - 36 receive some signal from Band 31 due to a light leak.

<u>Radiometric</u>
NEdl/NEdT/SNR
SBRS submitted a Waiver 073 for SNR. Bands 7 and 36 were identified as not meeting SNR for all channels, band this is mainly related to measurement difficulties.

Polarization
SBRS submitted a Waiver for polarization, Waiver WV055. The polarization measurements were obtained with a Polarization Source Assembly and a reflection between the PSA and MODIS (likely to be at thev first dicroic, D1). Consequently the residual polarization was determined by a Fourier extraction technique of the PSA test data. SNR for Bands 2 and 5 was too low to interpret this data. Residual polarization for Band 8 exceeds the desired amount (0.20), but there is no instrument specification for this band. The sensor is more polarization sensitive generally for the scan angles of 45 degrees. The specification does not extend to angles greater that 45 degrees. Bands 17 and 19 demonstrate greater residual polarization in the mirror side 1 data set than in the mirror side 2 data set.
RVS

1. These values are obtained using the characteristics of the fixed optics and a set of infrared s and p state polarized reflectance values from National Physical Laboratory measurements of PFM scan mirror witness samples. The characteristics of the PFM fixed optics are taken to be identical to those of the FM1 fixed optics. The FM1 fixed optics characteristics are inferred from an ambient high bay measurement of the FM1 RVS combined with NPL measurements of the FM1 scan mirror witness samples.
2. The use of a deep space scan to determine on-orbit the PFM RVS has been investigated. Our current understanding is that this data set will be helpful in validating the RVS for the Bands 33-36 at large scan angle.

Electronic Cross-talk

1. Data during the PFM Thermal Vacuum testing for Bands 5 - 7 and 20 - 30, including Band 26, were contaminated with electronic cross-talk. A fix was applied by changing resistors in the Space-viewing Analog Module electronics. No test data was obtained to verify the extent that this effect is reduced for PFM

Out-of-Family

The sensor meets linearity specification requirements. The SBRS memo documenting this performance is PL3095-O6399.

In this matrix, linearity is interpreted in the context of which channels within a band have a linearity characteristic which is different from that of the other channels within that band. In MCST terminology, we have called this characteristic, Out-of Family Channels. In the Reflected Solar Bands, we carry the calibration coefficients in the fnal product only on a band basis. Out-of-family behavior is handled as a correction within the dn* computation. The calibration algorithms are designed to correct for out-of-family behaviors.

Dynamic Range

SBRS Waiver for dynamic range is provided in Waiver WV077. The Band 32 out of specification related to the fire band detection. MCST analysis indicates possible saturation at radiances below 0.9 L_{max} for Bands 5 and 6. The data set showing this behavior was acquired before the electronic cross-talk was corrected, so we have no definitive knowledge for this characteristic.

Uncertainty

The SBRS Waiver on (absolute) radiometric accuracy is Waiver WV078 and WV062. these waivers are for the reflected solar bands. There are no waivers for the thermal emissive bands.

The reflected solar bands all are colored yellow because there are no measurements for the reflectance factor calibration product. The thermal emissive bands are indicated as green or yellow based on the analysis performed in conjunction with the electronic cross-talk repair studies.

References
A general reference for this material is "Specification Compliance and Calibration Data Books, Part IX - PFM, Compliance Matrix, " SBRS, Contract No. NAS5-30800, CDRL 222, May 1997.

Spatial

IFOV -- MCST Call # M0624, "PFM Spatial Performance Summary," F. Adimi, March 16, 1998

Co-Registration -- MCST Call # M0624, "PFM Spatial Performance Summary," F. Adimi, March 16, 1998

Modulation Transfer Function -- MCST Call # M0624, "PFM Spatial Performance Summary," F. Adimi, March 16, 1998

Transient Response -- MCST Reflected Solar Band Workshop February 11-12, 1999, Section IX, Scene Correction for Stray Light Contamination (Scattered Light Image Restoration Processing)

Spectral

Relative Spectral Response In-band Measurements
MODIS (MCST) Thermal Emissive Band Workshop, Miami, Fl, February 4-5, 1999, Section 7 PFM Relative Spectral Response T. Dorman and G. Godden.

Relative Spectral Response Out-of-band Measurements
MODIS (MCST) Thermal Emissive Band Workshop, Miami, Fl, February 4-5, 1999, Section 7 PFM Relative Spectral Response, T. Dorman and G. Godden.

Optical Cross-talk

1. MODIS Reflective Band Characterization and Algorithm, MCST Workshop, August 26-27, 1997, Stray Light and Crosstalk, Other PFM Instrument Characteristics, E Knght.
2. MODIS (MCST) Thermal Emissive Band Workshop, Miami, Fl, February 4-5, 1999, Section 10 Review of B31 Leaks into Bands 32-36, G. Godden.

Radiometric

NEdl/NEdT/SNR
Polarization
MCST Memo numbers on this topic are:

1. M0626 "PFM Polarization Results", C. Merrow, TBD, 1999
1. M0627 "PFM Polarization Analysis-Summary List of Memos", C. Merrow, TBD, 1999

RVS

1. The NPL measurements of the scan mirror witness samples was provided on November 24, 1998 in an attachment to an electronic mail message to godden@mcst.gsfc.nasa.gov from Nigel.Fox@NPL.co.uk.
2. Discussion on the utility of the deep space scan for MODIS PFM RVS is contained in MODIS (MCST) Thermal Emissive Band Workshop, Miami, Fl, February 4-5, 1999, Section 13 Deep Space Scan RVS Retrieval by G. Godden and C. Moeller.

Electronic Cross-talk

1. A Report on the Laboratory Testing and Status of a Hardware fix for Electronic Cross-talk and a Review of Principle Testing Options MODIS PFM, B. Guenther, Version 1.0, 14 August 1998.
2. Red Team Review of Electronic Cross-talk, MCST Presentation, July 9 - 10, 1998.

Out-of-Family

The infrared out-of-family channels are documented in the Infrared Workshop, Madison, September 11 - 12, 1997, Section 2.0, Summary of Test Data and Date Analysis, G. Godden.

Dynamic Range

This information is describe in MCST Call #M0625, Saturation of the PFM Reflective Band Detectors, G. Fireman, April 13, 1999.

Uncertainty

The uncertainty for the thermal emissive bands is documented in "White Paper on Options for MODIS PFM Calibration," Version 2.2, B. Guenther, November 2, 1998.